DOCUMENT RESUME

ED 280 686 SE 047 848

TITLE Research Matters...To the Science Teacher, 1987.
INSTITUTION National Association for Research in Science Teaching.
PUB DATE 87
NOTE 9p.; For the 1984 issues, see ED 273 489; for the 1985 issues, see ED 273 490. The 1986 issues are entered under individual titles; see ED 266 957-961.
PUB TYPE Reports - Descriptive (141)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Cognitive Style; Computer Uses in Education; Elementary School Science; Elementary Secondary Education; Instructional Improvement; Learning Modalities; *Metacognition; *Microcomputers; Science Education; *Science Instruction; Secondary School Science; Skill Development
IDENTIFIERS Concept Maps; *Science Education Research

ABSTRACT

Suggestions for instructional improvement are offered for science teachers in this compilation of research summaries on specific areas of science education. This series examines the topic areas of: (1) higher-order cognitive skills (focusing on developing operational definitions and classification schemes for cognitive skills); (2) microcomputers in science instruction (synthesizing research findings on the effectiveness of microcomputers in teaching and learning); (3) learning styles (describing several models or systems that have attempted to explain an individual's learning style); and (4) metacognitive strategies (highlighting the values of metacognitive and metaknowledge strategies and describing the functions of concept maps and vee diagrams in metacognitive learning). (ML)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

NARST
NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

ED280686

Research Matters . . . To the Science Teacher

DEFINITION AND ASSESSMENT OF THE HIGHER-ORDER COGNITIVE SKILLS

Audrey B. Champagne

Imagine glass cylinders containing different quantities of sand. Students are supplied with three cylinders, one of which is completely filled with sand, and an inclined board. They are encouraged to observe the motion of the cylinders as they roll down the incline. Then students are shown a fourth cylinder and asked to predict how that cylinder will roll down the incline. How would your students respond to this exercise? What evidence would convince you that a student had used a higher-order cognitive skill? Suppose your colleagues are also observing the exercise. Will they agree with your interpretations of the students' behavior? My experience suggests that you and your colleagues will probably not agree. However, this is an empirical question—if you doubt my premise, try the experiment. The exact manipulative exercise is not important, but having the students *and* some colleagues participate is crucial.

Observers interpret performance on tests of the higher-order cognitive skills differently because there are no agreed-upon operational definitions of this skills. Developing such definitions is difficult, because our understanding of the skills is limited. For example, we know very little about the relationships between the higher-order skills and the lower-orderdskills. Improved instruction and assessment of higher-order cognitive skills is contingent on developing operational definitions of those skills. This is the aim of this paper.

How are lower-order skills distinguished from higher-order skills?

- Are the two levels distinguished by age? Do children, by definition, engage only in lower-order thinking and adults engage only in higher-order thinking?
- Are the two levels distinguished by the frequency with which we observe them in the population? Are higher-order skills by definition rarer than lower-order ones?
- Is content the distinguishing characteristic? Are higher-order skills only exhibited in the context of a formal discipline—mathematics, physics, economics—or can they be exhibited in practical situations such as automobile repair or dressmaking?
- Are definitions of higher-order skills idiosyncratic—that is, does an observer categorize a skill as higher-order if it produces a solution to a problem that the observer could not do?

If you accept the assertion that operationally defining the higher-order thinking skills is difficult but potentially useful; then, you might try collecting and categorizing cognitive skills like naturalists collect and categorize plant and animal specimens. You can collect samples from practitioner journals, research journals in science education and the cognitive sciences, teachers' manuals for science textbooks, curriculum guides, and technical manuals for standardized science tests. When a number of skills have been identified, it is possible to build a taxonomy for the skills.

I found such a collection and categorization activity useful in illuminating some of the uncertainties in our understanding of the higher-order cognitive skills. The ordered list of skills that I collected is displayed in Figure 1. The list is quite long, but undoubtedly incomplete. You will have little difficulty collecting new skills and adding them to my list.

Figure 1 - A Collection of Cognitive Skills

Higher-Order Cognitive Skills
Lower-Order (Algorithmic)
Generic
Metacognitive
Assess Understanding
Assess Validity of Generalizations
Test Facts Against Rules of Evidence
Reasoning
Logical
Inductive
Deductive
Analogical
Creative
Verbal
Spatial
Qualitative
Quantitative
Discipline (Content) Specific
Task Specific
Problem Solving
Patterns of Knowledge
Generic Problem Schemata
Rate
Limit
Proportion/Ratio
Discipline
Formulas
Algorithms
Facts
Rules
Procedural Skills
Heuristics (Strategic Knowledge)
Evaluate Progress
Constraint Satisfaction
Progressive Refinement
Means-ends Analysis
Setting Goals
Monitoring Progress
Making and Adapting Plans
Problem Decomposition
Problem Decontextualization
Elaboration
Reasoning (Rule Based Information Processing)
Inquiry
Generic
Discipline Specific
Scientific
Discipline Knowledge
Procedural Knowledge (Conducting an Inquiry)
Planning and Implementing an Investigation
Problem Definition
Hypothesis Generation
Apparatus Selection
Observation
Data Management and Analysis
Identify Patterns
Graphing
Extrapolation
Generalization
Modeling Mathematical
Learning

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Glenn Markle
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

The first sort in my taxonomy produces two categories of cognitive skills, higher-order and lower-order. Leaving aside for the moment which skills belong in which category, and which criteria influence this decision, the relationship between the higher- and lower-order

SE 047 948

skills is an issue central to the practice of science teaching and to theory in psychology. Are the higher-order skills simple concatenations of lower-order ones or are the two kinds of skills qualitatively different? Your answer to this question will profoundly effect the way you teach these skills. If you believe that higher-order skills are concatenations of the lower ones, your teaching strategy will probably be based on analysis of higher-order skills that breaks into simpler skills. Each of the simpler skills is then taught. The assumption underlying this strategy is that when the individual skills are all learned, the higher-order ones will be also. This basic idea of building skills from the bottom up pervades our educational practice and was the theoretical basis for the instructional model used in *Science: A Process Approach* (SAPA).

If, on the other hand, you believe that higher-order cognitive skills are qualitatively different from concatenations of lower-order ones, your instruction will probably be more like that used in the Elementary Science Study (ESS) materials. The assumption underlying the instructional model used in the ESS materials, is that the higher-order skills develop as the result of understanding related phenomenon.

My taxonomy proceeds to sort the higher-order skills into three categories: problem solving, learning, and inquiry (See Figure 2). There are other ways in which they can be sorted, such as according to the kind of cognitive task, they might have been sorted according to the discipline or context in which the skills are demonstrated. The result of a discipline-based sort is illustrated in Figure 3. These sorts produce different categories and illuminate another important issue that has both practical and theoretical importance: Are the higher-order skills task or discipline specific?

Figure 2 - Higher-Order Cognitive Skills Sorted According to Task

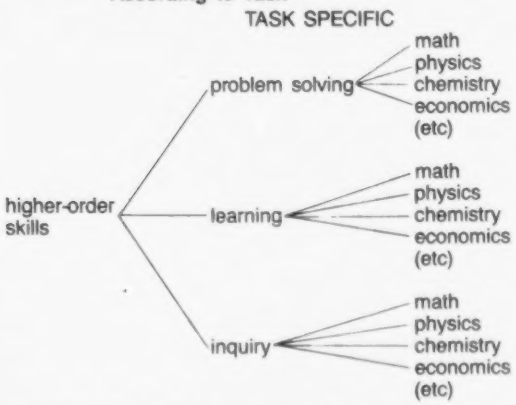
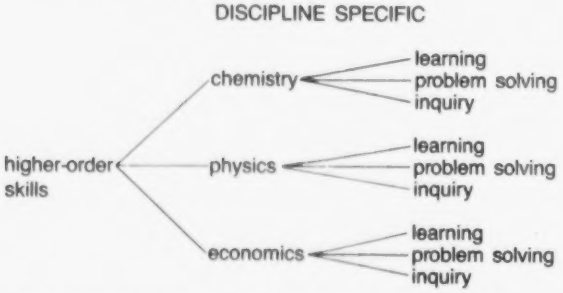


Figure 3 - Higher-Order Cognitive Skills Sorted According to Discipline



This question is the subject of major research efforts in cognitive psychology. The goal of this research is to understand the relationship between knowledge about a discipline and performance of problem solving, learning, and inquiry skills in the context of the discipline. The current research in cognitive science implicates discipline knowledge in successful performance of most higher-order thinking skills. Studies of experts' problem solving confirms the importance of discipline knowledge and illuminates important differences in the discipline knowledge 'of experts and novices.[1] Experts' knowledge is highly structured in ways that facilitate problem solution. This suggests that when students practice the solution of problems, they are not only learning how to solve the problems. They are also restructuring knowledge of the discipline in ways that will facilitate future problem solution. Problem solution serves as both a method for learning (structuring) content and a way of demonstrating understanding of the content. Another significant characteristic of experts' knowledge is that much of it is automatic. The simple formulas, algorithms, facts, and rules of the discipline are recalled and applied so rapidly that most experts do not even mention that they are using them unless specifically asked. This suggests that some memorization is in order if students are to act like experts. They just can't do problems without basic information.

Experts have another kind of knowledge that facilitates problem solution. This is knowledge about problem schemata. Upon reading a textbook problem, an expert will often identify it as a momentum problem, or a kinetic energy problem, or a mixture problem, or a rate problem. Experts categorize the problem by comparing it with problem schemata stored in their memories. No matter what the physical context described in the particular problem, the expert immediately matches it with the appropriate problem type in her repertoire of problem schemata. Having categorized the problem the expert also has available a method for solving the problem.

With all of this talk about the importance of knowledge, you might get the idea that there are no generic problem solving skills. This is not the case. Expert problem solvers also exhibit procedural skills that facilitate problem solving. Some of those skills are listed in Figure 1. Some investigators in the field call these procedural skills heuristics. Others call them strategic knowledge. The use of these different terms further confuses the distinction between knowledge and cognitive skills.

The many theoretical issues surrounding the relationship between knowledge and cognitive skills are by no means resolved. In addition, the theoretical issues have corresponding instructional ones. Do the higher-order skills transfer? In practice, that is, in teaching and testing, the skills are generally treated as if they are discipline specific. However, educators and laymen alike often talk about the skills as if they are generic. If students learn to think scientifically in science class, will they think scientifically in contexts outside science class? Popular belief aside, the mounting evidence is that students leave their scientific knowledge and thinking skills in science class and use other knowledge and skills in their encounters with the real world.

Renewed emphasis on teaching the higher-order skills requires that science teachers reconsider some basic questions about the relationship between cognitive skills and discipline learning. Are these skills best taught/learned in the context of a discipline, or in separate skill-development courses that focus on rational thinking, problem solving, inquiry, and critical or creative thinking? Do the higher-order cognitive skills transfer? If so, under what conditions? Are the sciences particularly good disciplines for learning the higher-order skills? If so, how should instruction be modified to produce better results? The answers to these questions are not at all clear.

Much of the work in cognitive psychology suggests that use of the higher-order cognitive skills is closely linked with discipline specific knowledge. This conclusion is based primarily on research on problem-solving and learning-to-learn skills. Consequently, the conclusion is limited to these specific higher-order thinking skills. The findings may be quite different for higher-order skills such as metacognition, and logical, analogical, inductive or deductive reasoning.

All of this comes back to the original point: As a community of educational practitioners and researchers, we need to be more scientific in our approach to teaching and assessing the higher-order cognitive skills. Common operational definitions for these skills are a necessary condition for more scientific teaching and research to attain the all-important goal of science education: scientific thinking in students.

Selected References

Segal, J. W., Chipman, S. F. & Glaser, R. (Eds.) (1985). *Thinking and Learning Skills. Volume I: Relating Instruction to Research.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

deBono, E. (1976). *Teaching Thinking.* London: Temple Smith.

Lockhead, J. & Clement, J. (Eds.) (1979). *Cognitive Process Instruction.* Philadelphia: Franklin Institute Press, 1979.

Linn, M. C., Pulos, S., Gans, A. (1981). Correlates of formal reasoning: Content and problem effect, *Journal of Research in Science Teaching, 18,* 435-447.

Dr. Audrey B. Champagne is a senior program analyst in the Office of Science and Technology Education of the American Association for the Advancement of Science. She is a member of the National Association of Research in Science Technology, an association dedicated to the improvement of science teaching through research.

[1]An expert in these studies is an advanced graduate student or PhD. A novice is typically a junior or senior majoring in a discipline. The problems used in these studies come from texts used in elementary or intermediate undergraduate courses.

The National Association For Research in Science Teaching is an organization that seeks to improve science teaching through research. For further information, contact the NARST Executive Secretary:

Dr. Glenn Markle
401 Teacher College
University of Cincinnati
Cincinnati, Ohio 45221

NARST
NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

Research Matters . . . To the Science Teacher

IMPROVING SCIENCE INSTRUCTION WITH MICROCOMPUTERS

By James D. Ellis

A Fantasy

Picture yourself in the science classroom of the 1990's. The curriculum and learning activities are aligned with the recommendations made during the 1980's, in the more than 40 reports responding to the national crisis in education. You, as the teacher, are charged with preparing students to participate in a society in which all citizens must cope daily with scientific and technologic problems and issues. Information technologies have revolutionized the economy and your daily living.

Microcomputers have revolutionized what you teach, how you teach, and how your students learn science. Until the microcomputer, never before have you had the potential to have all of your students:

- develop thinking skills in a variety of ways;
- work at their own pace while studying material tailored to their individual needs and interests (remediation and enrichment);
- understand scientific and technologic concepts in depth; and,
- do science in an intellectually honest way.

Never before have you had the potential for:

- diagnosing the level of student knowledge and skills;
- prescribing learning tasks appropriate to the needs of the student;
- evaluating, monitoring, and reporting student progress;
- adapting and developing learning materials for your tailor-made curriculum; and,
- spending most of your time assisting students directly with learning problems.

Will the microcomputer activate a higher level of educating than we have attained before, thus enabling us to approach the goal of a scientific and technologic literate citizenry? Or, is the picture presented above a fantasy?

The Reality

The status of educational computing in science is not consistent with the science instruction of the 1990's portrayed by leaders of the technologic revolution. Becker (1986), Lehman (1985), and Tinker (1984) point out that currently:

- thirty minutes of computer time per day for all students enrolled is available at only seven percent of high schools and roughly two percent of elementary and three percent of middle schools;
- the majority of computers are located in computer laboratories;
- only one-third of student time on computers involves instruction in content areas;
- only 15-20 percent of the time computers are being used for science instruction;
- only six percent of high school science teachers use microcomputers at least one hour per week per class;
- only one microcomputer is available for use in the majority of science classrooms;
- science teachers use the computer more to present information and less as a tool for learning;
- in 1984, on the average, software covered fewer than 15 topics per science course per grade level;
- two-thirds of the software in science is drill-and-practice and games; and,
- the majority of available software is trivial, unimaginative, and does not use microcomputers well.

Recent research has shed light on the effectiveness of microcomputers in teaching and learning. In a synthesis of 42 research studies, Bangert-Downs, Kulik, and Kulik (1985) found that in secondary schools instruction involving computers was only slightly more effective than "traditional instruction" without computers. Even in those studies where computers enhanced learning, little is known about how programs using microcomputers increased learning. Clark (1983) contests the significance of the research findings and suggests that computers "are mere vehicles that deliver instruction but do not influence student achievement anymore than the truck that delivers our groceries causes changes in our nutrition."

Researchers are determining how the computer can enhance science education. Zietsman and Hewson (1986) report that remediation of certain misconceptions in physics can be effected via a microcomputer simulation. In a study of "Rocky's Boots", a simulation and logic game for middle-aged students, Stein and Linn (1985) concluded that to achieve significant student performance with even high-quality software, instruction must emphasize the critical features of the program and provide activities and structure in addition to the interaction with the computer software. Wiser (1985) found that students using a unit on heat and temperature, including microcomputer-based laboratory hardware and software, performed better than students using traditional paper-and-pencil laboratory methods.

Bridging the Gap

Sufficient results from prolonged use of educational computing in science teaching do not exist to form conclusions as to its effectiveness; because, too few science teachers are using the computer as a significant part of their instruction. As Okey (1984) and Watson (1983) point out, few science teachers have participated in instruction using a computer, or learned how to use the computer for instructional purposes.

What are the knowledge and skills needed by a science teacher to use microcomputers to enhance learning and teaching? Ellis and Kuerbis (1985a) identified and validated 22 essential computer literacy competencies for science teachers. The competencies are described in the following categories:

- *computer awareness* — how to operate a microcomputer, how it affects education and other fields;
- *applications in science teaching* — how the microcomputer is used to enhance learning and teaching;
- *implementation of educational computing* — how to overcome barriers to integrating the microcomputer into science teaching;
- *evaluation of software* — how to identify, evaluate, and adopt materials for educational computing in science teaching;
- *resources* — how to identify, evaluate, and use a variety of sources of information regarding computer uses in science education; and,
- *attitudes* — the development of positive attitudes and values about the use of educational computing in science teaching.J

Note that computer programming was not a skill considered essential in using the microcomputer successfully in science teaching.

In a National Science Foundation project, Ellis and Kuerbis (1985b) have been developing and implementing a curriculum—*ENLIST Micros*—to prepare pre- and in-service science teachers grades K-12, to use the microcomputer to enhance learning and teaching. More than 500 science teachers around the nation have used the materials and recently, with support from NSF, a three-year project has been initiated to help 260 science teachers from 22 school districts in Colorado integrate educational computing into their instruction. The following discussion is based on my experience in these projects and on the research literature on educational computing.

Using computers in your science classroom can be approached in three stages—exploration, accommodation, and integration. The first stage is to *explore* exciting applications in a limited manner. During the exploration stage, you gain limited access to microcomputers that are usually located in a computer lab or preferably one microcomputer is checked out from the media center. You should try applications that seem to have merit and evaluate their effectiveness. Usually, teachers are attracted first to management software, such as "Printshop" that will produce banners and signs for bulletin boards or a gradebook program that facilitates record keeping. Additional management applications you should explore at this time are word processing of instructional and administrative materials and databases used for organizing information such as equipment and materials. During this stage, you should explore instructional applications such as simulations and microcomputer based laboratory materials. Try to find programs that are highly motivating or very practical. Usually, these programs are used to enrich existing instruction and improve normal instructional procedures and activities.

Next, begin to *accommodate* instruction to the requirements of microcomputer use. Teachers usually have access to one computer in their classroom. We encourage you to try a variety of approaches to using that computer such as demonstrating a concept to the whole class, assigning small groups in cooperative learning situations to complete a task at the computer while groups are working at other stations completing non-computer tasks, or using the computer to provide individualized learning opportunities for enrichment or remediation. During this accommodation stage, you can investigate how the computer can enrich teaching.

The final stage is to *integrate* educational computing into your ongoing instructional activities and by selecting computer activities that contribute to central goals of your program.

Often integration of educational computing into instruction can mean a redefinition of goals and approaches to teaching and learning. In the most complete implementation, the potentials described earlier may be achieved. However, most teachers will adjust incrementally to educational computing and focus on specific applications that they find effective and worthwhile.

References

Bangert-Downs, R.L., J. A. Kulik, and C. C. Kulik. "Effectiveness of Computer-Based Education in Secondary Schools." *Journal of Computer-Based Instruction*. V12(3), pp. 59-68, 1985.

Becker, Henry Jay. "Instructional Uses of School Computers." No. 1, June 1986, Baltimore, MD: John Hopkins University.

Clark, Richard E. "Reconsidering Research on Learning from Media." *Review of Educational Research*. V53(4), pp. 445-459, Winter, 1983.

Ellis, James D. and Paul J. Kuerbis. "Development and Validation of Essential Computer Literacy Competencies for Science Teachers." Paper presented at National Association for Research in Science Teaching. French Lick Springs, Indiana. April, 1985.

Ellis, James D. and Paul J. Kuerbis. *ENLIST Micros, experimental edition*. Colorado Springs, Colorado: BSCS, The Colorado College, 1985.

Okey, James R. "Integrating Computing into Science Instruction." *Journal of Computers in Mathematics and Science Teaching*, V4(2), pp. 14-18, 1984-85.

Stein, Joanne S. and Marcia C. Linn. "Capitalizing on Computer-"Based Interactive Feedback." in *Children and Microcomputers: Research on the Newest Medium*. Chen, M. and W. Paisley (eds.). Beverly Hills, CA: Sage Publications, 1985, pp. 213-227.

Tinker, Robert F. *Science and Mathematics Software Opportunities and Needs (SAMSOM) Project, (Final Report)*. Technical Education Research Centers, 1696 Massachusetts Avenue, Cambridge, MA. August, 1984.

Wiser, M. "Designing a Microcomputer Based Laboratory to Induce the Differentiation Between Heat and Temperature in Ninth Graders." Technical Report 85-17. Educational Technology Center, Harvard Graduate School of Education, Cambridge, MA. 1985.

Zietsman, Aletta I. and Peter W. Hewson. "Effect of Instruction Using Microcomputer Simulations and Conceptual Change Strategies on Science Learning." *Journal of Research in Science Teaching*. V23(1), pp. 27-39. 1986.

Dr. James D. Ellis is senior staff associate at the Biological Sciences Curriculum Study, The Colorado College, Colorado Springs, Colorado. He is a member of the National Association for Research in Science Teaching, an organization that seeks to improve science teaching through research.

The National Association For Research in Science Teaching is an organization that seeks to improve science teaching through research. For further information, contact the NARST Executive Secretary:

Dr. Glenn Markle
401 Teacher College
University of Cincinnati
Cincinnati, Ohio 45221

For more information about the ENLIST-Micros project contact: Dr. James D. Ellis, BSCS, 1115 N. Cascade Avenue, Colorado Springs, Colorado 80903.

NARST
NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

Research Matters . . . To the Science Teacher

LEARNING STYLES AND SCIENCE TEACHING

By Paul J. Kuerbis

Some students blurt out responses to questions before the questions are completed. Some students reflect on the answer to a question. Some students thrive on activities in which they can cooperate with their peers. Some students thrive on field trips. And, some students give evidence that lectures and readings are effective teaching/learning approaches, while their classmates may benefit from a "hands-on" and/or visual approach. All of the behaviors just described are individual ways that students learn—the paragraph is a collage of what researchers call, learning styles.

The concept of learning style has a long history that includes both psychology and education. The Greek, Hippocrates, identified four personality types: Sanguine, Choleric, Melancholy, and Phlegmatic. In the early 20th century, German psychologists studied cognitive style differences. Carl Jung published a book on psychological types in 1921. In subsequent years, the American psychologists such as Gordon Allport, Herman Witkin, Katherine Briggs, and her daughter Isabel Briggs Myers conducted extensive research on different thinking styles. This effort waned during the 1950's and early 1960's when researchers found little correlation between individual styles and success in school. These were also times when educators, notably science educators, focused their energies on curricula and the developmental psychology of Jean Piaget.

In the early 70's work on personality styles, particularly as they related to students in school settings, began to appear in the literature. During those years, several related terms appeared. *Learning modalities* was a term used to describe the various sensory channels (e.g., auditory, tactile, visual) through which learners input and output information. *Cognitive style* was used to describe ways individuals think or work with information (e.g., random versus sequential). Both of those terms were subsumed under the broad term, learning style.

Learning style is a term educators use to describe the way we perceive, interact with, and respond to the learning environment. It is a broad rather than specific term; consequently, the concept is defined differently by different researchers and practitioners. Nonetheless, most agree that learning style is a consistent way of functioning that learners exhibit. Learning style has cognitive, affective, and physiological dimensions that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment. Style has a cognitive dimension since students perceive and gain knowledge differently. Some need concrete experiences, while others comprehend a concept through a lecture. Learners also show differences in how they process information and in what they do with it. Some learners are convergent in their thinking while others are divergent. Some students process information in a linear fashion, while others are random or approach a task globally. The affective dimension embodies the motivational, judgmental, valuing and emotional aspects of style. For example, some students are logical and straightforward in approaching a problem while others seem to be led more by their hearts than their heads. Some students benefit from structure, while others need very little guidance. The physiological dimension includes responses that are biologically based. Some students do their best work early in the morning, while others work better in the late morning or early afternoon. Environmental factors such as sound, light, and temperature can all influence student learning through the physiological dimension.

Some Learning Style Models

During the past decade numerous models or systems of learning styles have been proposed. Most address only one or two of the three dimensions of the general learning style model. Below, several of the more popular models are outlined. Each model has an instrument for assessing an individual's learning style. Each system also has supplemental materials aimed at assisting teachers who wish to use the model as basis for making decisions concerning the curriculum and instruction.

The current model developed by Dunn and Dunn contains five levels, each with several traits: Environmental (sound, light, temperature, room/furniture design); Emotional (motivation, persistence, responsibility, structure); Sociological (self, pairs, peers, team, adult, varied); Physical (modalities, intake, time of day, mobility); and Psychological (global-analytical, hemisphericity, impulsive-reflective). The "Learning Styles Inventory" can be used in grades 3-12 and assesses each student's strong positive and strong negative preferences for 18 elements of style. Applying the model in science classrooms should focus on matching teaching styles with learning styles using a diagnostic-prescriptive approach. In association with National Association of Secondary School Principals (NASSP) and Association for Supervision and Curriculum Development (ASCD), the Center for Learning Styles at St. John's University (New York) publishes a quarterly newsletter and numerous other resources designed to assist classroom teachers in the application of the model.[1]

Anthony Gregorc's model focuses on the mediation abilities of the human mind: perception and ordering. He contends that individuals perceive the world on a continuum that ranges from concrete to abstract and they order information and knowledge on a continuum that ranges from sequential to random. These two continua combine to give four distinct patterns of learning style behavior:

- *Concrete Sequential* students learn best from real objects and events and when information is presented in a logical order.
- *Abstract Sequential* students learn best from abstract approaches (e.g., lecture, readings) which are highly sequential.
- *Concrete Random* students benefit from real experiences, but need to approach learning in a more haphazard, vicarious manner.
- *Abstract Random* students can learn from abstract presentations but need to order information their own way: randomly.

Kathleen Butler has translated Gregorc's model into a teaching-learning model. Her book is an excellent source of ideas teachers can use to modify their preferred style of teaching and add variety to their teaching to meet the learning style needs of students. The Gregorc-Butler approach to application emphasizes the importance of "guided mismatch" so that learners strengthen their abilities in their non-preferred style areas.[2]

Some researchers have built learning style models upon the psychological theory proposed by Carl Jung. Foremost among these have been Katherine Briggs and her daughter, Katherine Briggs Myers (The Myers-Briggs Type Indicator), and more recently, Robert Hanson, Harvey Silver and Richard Strong. The Jungian theory posits four functions: two ways of perceiving (sensing and feeling) and two ways of judging data (thinking and feeling). According to the Hanson, Silver and Strong group, combining these gives four basic learner types:

- The *Sensing-Thinker* learner is realistic and pragmatic and perceives the world through the senses rather than through ideas. For these students, employ journals, role playing and consensus decision making.
- The *Sensing-Feeling* learner perceives with his senses but makes decisions based on personal feelings rather than impersonal logic. For these students, employ workbooks, demonstrations and field trips.
- The *Intuitive-Thinking* learner is intellectual and knowledge-oriented and looks beyond what is concrete or tangible to the world of abstractions and possibilities. For these students, employ independent research projects, lectures and debates and inquiry.
- The *Intuitive-Feeling* learner uses his intuition rather than his senses and looks to what is possible rather than what is. For these students, use guided imagery and open-ended discussions.

Application of the model is through both matching strategies and the provision of variety so that a teacher is directed to use teaching approaches suited for all four types of learners.[3]

Bernice McCarthy's model of learning and teaching styles is based on the work of David Kolb. Kolb, like Jung, posited that the human mind has both perceiving and processing qualities. The perceiving continuum ranges from concrete to abstract. Sensor/feelings tend to be more concrete in their perception, while thinkers tend to be more abstract. The processing continuum ranges from active to reflective. Active processors initiate activities and try things firsthand. Reflective processors watch what's happening and reflect before acting. Combining the two continuum results in four learner types:

- *Type One: Concrete Experience.* For this learner, personal meaning and social interaction are important.
- *Type Two: Reflective Observation.* For this learner, information, facts and logic are important.
- *Type Three: Abstract Conceptualization.* For this learner, sensory experience and application are important.
- *Type Four: Active Experimentation.* For this learner, intuition, synthesizing and experience are important.

McCarthy proposes that we reach the four basic types of learners by designing lessons and units of study that use strategies which systematically rotate through the four types of learners. Teachers should begin with a personal experience, then move to presentation of information followed by application of that knowledge and conclude with experimentation. Furthermore, within each of the four modes, left and right brain activities should be included. Recently, McCarthy and Bill Hammond and Bob Samples have published a resource of science teaching ideas.[4]

Teaching with Style

The evidence strongly suggests that students' achievement can be improved when teachers address the learning styles of students. Until we know more about the specific effects of matching and mismatching teaching styles with individual learner styles, classroom teachers should utilize the following guidelines:

- Guard against over-teaching with *your* preferred style.
- Help students identify *their* preferred style(s).
- Provide a variety of teaching approaches so that all students have the opportunity to learn through their preferred style and are challenged to diversify and use other styles.

Research on learning styles provides support for use of a variety of instructional strategies in the science classroom. There is need for laboratory, discussion, demonstration, group projects and even lectures. To use a teaching approach extensively and to apply various approaches in anything less than a systematic manner is a failure to recognize the importance of students "learning styles" and your ability to enhance learning through application of this line of resource to science teaching.

References

1. Information on the Dunn's model, including a newsletter, sample units of study and other resources may be obtained from: The Learning Styles Network, St. John's University, Jamaica, New York 11439.
2. Resources on the Gregorc-Butler model can be obtained from: Gabriel Systems, Inc., Box 357, 147 Main Street, Maynard, MA 01754.
3. Resources on the Hanson, Silver, Strong and Associates, P. O. Box 402, Moorestown, N.J. 08057.
4. Resources on the McCarthy model can be obtained from: EXCEL, Inc., 600 Enterprise Drive, Suite 101, Oak Brook, IL 60521.

Paul J. Kuerbis is Professor of Education at The Colorado College. He is a member of the National Association for Research in Science Teaching, an organization dedicated to improving science teaching through research.

The National Association For Research in Science Teaching is an organization that seeks to improve science teaching through research. For further information, contact the NARST Executive Secretary:

Dr. Glenn Markle
401 Teacher College
University of Cincinnati
Cincinnati, Ohio 45221

NARST
NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

Research Matters . . . To the Science Teacher

METACOGNITIVE STRATEGIES TO HELP STUDENTS LEARNING HOW TO LEARN

By Joseph D. Novak

Strategies to help people learn go back to our educational origins. For example, Socrates developed the technique of Socratic questioning, where he sequentially asked questions to draw out the knowledge he believed was in the minds of all persons, slave or emperor. While there is still much we do not know about learning, we know that knowledge must be acquired by the individual, and that knowledge previously learned influences the acquisition of new knowledge. We know that learning can be essentially by *rote* memorization, with little interaction with previous learning (and usually very short retention) to highly *meaningful* learning where the learner integrates new concepts, propositions and images into previously acquired structures. We know that the learner *chooses* to learn by rote or meaningfully and part of the task of teachers is to help the learner choose powerful meaningful learning approaches. *Metacognitive* strategies are strategies that empower the learner to take charge of her/his own learning in a highly meaningful fashion.

Metacognitive strategies include *metalearning*, or learning about meaningful learning, and *metaknowledge*, or learning about the nature of knowledge. Our research has shown that few of the students we have studied at the secondary or college level have had any formal metacognitive instruction. Some students have had instruction on "how to study", but this deals primarily with techniques for time management, concentration, test taking, and memorization. Metalearning strategies help the learner understand that meaning derives from the concepts and concept relationships we have and new relationships we assimilate into our existing knowledge frameworks. The learner becomes aware of the limited capacity of Short-Term Memory (STM); only about seven "chunks" of knowledge can be manipulated at a time; and the important role that the organization of knowledge in Long-Term Memory (LTM) plays in what we perceive in a message and nature of the "chunks" we can use in STM. Thus a learner who has knowledge organized into large, integrated conceptual frameworks can assimilate more related knowledge in less time and with greater usefulness.

Metaknowledge strategies help students to understand that concepts are constructed from perceived regularities in objects or events and that we use language or symbolic labels to designate these regularities. Creativity is involved in constructing new concepts, and meaningful learning is the principal process by which humans acquire most of their usable knowledge. The interplay between various concepts, principles, theories, and philosophies as they are involved in selecting or interpreting observed objects or events is a necessary part of metaknowledge instruction. When successful, metaknowledge strategies lead to understanding how humans *construct* knowledge and also offer practice in the process of constructing knowledged*claims* and value *claims* about some observed regularities in objects and/or events. Thus a science student comes to understand how a laboratory experiment illustrates the ways in which scientists have constructed knowledge claims about the observed events or objects. They also learn that all knowledge claims are accompanied by at least an implied value claim (i.e., this knowledge claim is *worthwhile*), and they learn to discriminate between knowledge claims and value claims.

In our work at Cornell University, we have developed two tools that aid in metacognitive learning. The *concept map* (see Figure 1) when constructed by students helps to illustrate that we use language labels to construct concept and propositional relationships about a domain of knowledge. The concept map thus serves as a tool to illustrate the hierarchical, conceptual/propositional nature of knowledge. It also serves as a tool to help learners organize their cognitive frameworks into more powerful, integrated patterns. Thus, concept maps serve both as metaknowledge and metalearning tools.

Vee diagrams (see Figure 2) are a tool to help students construct the interacting set of elements that are involved in knowledge production. Vees serve as a scaffolding or normative device assuring that all of the elements receive due consideration in the process of seeking knowledge and value claims directed by the focus question. Our experience has been that Vee diagramming is more challenging than concept mapping for both students and teachers. This derives in part from the *positivist* philosophy embedded in most school and college learning, whereas Vee diagramming is rooted in an event-centered, *constructivist* philosophy now generally accepted by philosophers (C. F. Brown, 1979; K. Popper, 1982; E. von Glaserfeld, 1984).

Concept maps and Vee diagrams are valuable tools that help students "unpack" the knowledge in text, laboratory or lectures, and they are powerful tools for curriculum design. These metacognitive tools show promise not only for the improvement of learners, but also for the empowerment of teachers and curriculum planners.

References:

Bransford, John. (1979) *Human Learning, Understanding and Remembering*. Belmont, CA: Wadsworth.

Brown, H. I. (1979) *Perception, Theory and Commitment: The New Philosophy of Science*. Phoenix Edition. Chicago: University of Chicago Press.

Mayer, Richard E. (1983) *Thinking, Problem Solving, Cognition*. New York: W. H. Freeman.

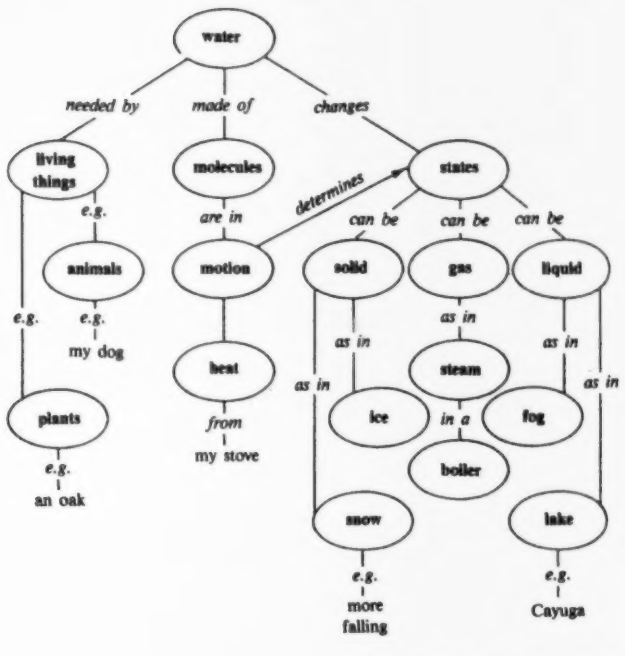
Novak, Joseph D. (1985) "Metalearning and Metaknowledge Strategies to Help Students Learn How to Learn." In Leo West and Leon Pines (eds) *Cognitive Structure and Conceptual Change.* San Diego, CA: Academic Press.

Novak, Joseph D., D. Bob Gowin and Gerard T. Johansen. (1983) "The Use of Concept Mapping and Knowledge Vee Mapping with Junior High School Science Students." *Science Education* 67 (5).

Popper, Karl. (1982) *Unended Quest: An Intellectual Autobiography.* London: Open Court.

von Glaserfeld, Ernst. (1984) "Reconstructing the Concept of Knowledge." Paper presented at the Seminar on Constructivism, Archives of Jean Piaget. Geneva.

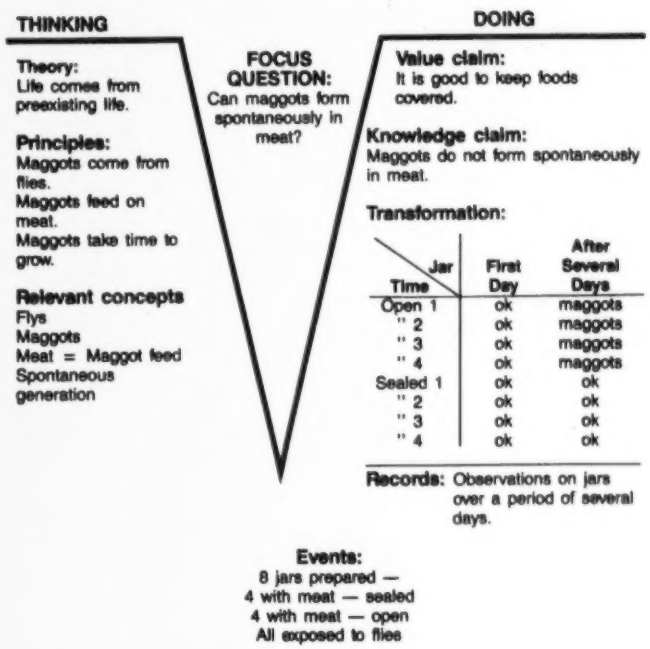
Figure 1. *Learning how to learn*



A concept map for water showing some related concepts and propositions. Some specific examples of events and objects have been included (in Roman type outside ovals).

Figure 2.

The use of the Vee for evaluation



A Vee diagram prepared from the description of an experiment in a high school biology textbook. This kind of analysis helps students to focus carefully on relevant details of an experiment.

Dr. Joseph P. Novak is Professor of Education at Cornell University. He is a member of the National Association for Research in Science Teaching, an organization that actively improves science teaching through research.

The National Association For Research in Science Teaching is an organization that seeks to improve science teaching through research. For further information, contact the NARST Executive Secretary:

Dr. Glenn Markle
401 Teacher College
University of Cincinnati
Cincinnati, Ohio 45221

For further information on this topic, contact Dr. Joseph D. Novak, Department of Science and Mathematics Education, Cornell University, 404 Roberts Hall, Ithaca, New York 14853-5901.